

entors: Wellington et al.
Appl. Ser. No.: 09/841,490
Atty. Dkt. No.: 5659-01100

Amendments to the Claims:

The following lists all claims and their status:

1-1057. (canceled)

1058. (previously presented): A method of treating a hydrocarbon containing formation *in situ*, comprising:

providing heat from one or more heaters positioned in one or more wellbores to at least a portion of the formation;

establishing a pyrolysis zone in at least the portion of the formation;

allowing the heat to transfer from the one or more heaters to the pyrolysis zone of the formation;

controlling a pressure and a temperature in at least a majority of the pyrolysis zone, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure;

controlling a pressure in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than 25; and

producing a mixture from the formation.

1059. (previously presented): The method of claim 1058, wherein the one or more heaters comprise at least two heaters, and wherein superposition of heat from at least the two heaters pyrolyzes at least some hydrocarbons in the pyrolysis zone of the formation.

1060. (previously presented): The method of claim 1058, wherein at least one of the heaters comprises an electrical heater.

1061. (previously presented): The method of claim 1058, wherein at least one of the heaters comprises a surface burner.

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1062. (previously presented): The method of claim 1058, wherein at least one of the heaters comprises a flameless distributed combustor.

1063. (previously presented): The method of claim 1058, wherein at least one of the heaters comprises a natural distributed combustor.

1064. (canceled)

1065. (currently amended): The method of claim 1058, wherein controlling the temperature comprises maintaining a temperature within-in the pyrolysis zone in a pyrolysis temperature range.

G | 1066. (previously presented): The method of claim 1058, further comprising controlling a heating rate such that an average heating rate of the pyrolysis zone is less than about 1 °C per day during pyrolysis.

1067. (previously presented): The method of claim 1058, wherein providing heat from the one or more heaters to at least the portion of the formation comprises:

heating a selected volume (V) of the hydrocarbon containing formation from the one or more heaters, wherein the formation has an average heat capacity (C_v), and wherein the heating pyrolyzes at least some hydrocarbons in the selected volume of the formation; and

wherein heating energy/day (P_{wr}) provided to the selected volume is equal to or less than $h^*V^*C_v^*\rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (h) of the selected volume is about 10 °C/day.

1068. (canceled)

1069. (previously presented): The method of claim 1058, wherein providing heat from the one or more heaters comprises heating the pyrolysis zone such that a thermal conductivity of at least a portion of the pyrolysis zone is greater than about 0.5 W/(m °C).

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1070. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons having an API gravity of at least about 25°.

1071. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons, and wherein about 0.1 % by weight to about 15 % by weight of the condensable hydrocarbons are olefins.

1072. (original): The method of claim 1058, wherein the produced mixture comprises non-condensable hydrocarbons, and wherein about 0.1 % by weight to about 15 % by weight of the non-condensable hydrocarbons are olefins.

1073. (original): The method of claim 1058, wherein the produced mixture comprises non-condensable hydrocarbons, wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons is less than about 0.15, and wherein the ratio of ethene to ethane is greater than about 0.001.

1074. (previously presented): The method of claim 1058, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is nitrogen.

1075. (previously presented): The method of claim 1058, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is oxygen.

1076. (previously presented): The method of claim 1058, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is sulfur.

1077. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons, wherein about 5 % by weight to about 30 % by weight of the

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condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

1078. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons, and wherein greater than about 20 % by weight of the condensable hydrocarbons are aromatic compounds.

1079. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 5 % by weight of the condensable hydrocarbons comprises multi-ring aromatics with more than two rings.

1080. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons, and wherein less than about 0.3 % by weight of the condensable hydrocarbons are asphaltenes.

1081. (original): The method of claim 1058, wherein the produced mixture comprises condensable hydrocarbons, and wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons are cycloalkanes.

1082. (previously presented): The method of claim 1058, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure, and wherein the molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmosphere absolute pressure.

1083. (original): The method of claim 1058, wherein the produced mixture comprises ammonia, and wherein greater than about 0.05 % by weight of the produced mixture is ammonia.

1084. (original): The method of claim 1058, wherein the produced mixture comprises ammonia, and wherein the ammonia is used to produce fertilizer.

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1085. (previously presented): The method of claim 1058, further comprising controlling the pressure in at least a majority of the pyrolysis zone of the formation, wherein the controlled pressure is at least about 2.0 bars absolute.

1086. (previously presented): The method of claim 1058, further comprising controlling formation conditions to produce a mixture of condensable hydrocarbons and H₂, wherein a partial pressure of H₂ in the mixture is greater than about 0.5 bar.

1087. (original): The method of claim 1086, wherein the partial pressure of H₂ is measured when the mixture is at a production well.

1088. (previously presented): The method of claim 1086, wherein controlling formation conditions comprises recirculating a portion of hydrogen from the mixture into the formation.

1089. (previously presented): The method of claim 1058, further comprising:
providing hydrogen (H₂) to the pyrolysis zone to hydrogenate hydrocarbons in the pyrolysis zone; and
heating a portion of the pyrolysis zone with heat from hydrogenation.

1090. (currently amended): The method of claim 1058, wherein the produced mixture comprises hydrogen and condensable hydrocarbons, ~~the method further comprising and~~ hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

1091. (previously presented): The method of claim 1058, wherein allowing the heat to transfer increases a permeability of a majority of the pyrolysis zone to greater than about 100 millidarcy.

1092. (previously presented): The method of claim 1058, wherein allowing the heat to transfer increases a permeability of a majority of the pyrolysis zone such that the permeability of the majority of the pyrolysis zone is substantially uniform.

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1093. (previously presented): The method of claim 1058, further comprising controlling a heating rate to yield greater than about 60 % by weight of condensable hydrocarbons, as measured by the Fischer Assay.

1094. (previously presented): The method of claim 1058, wherein producing the mixture comprises producing the mixture in a production well, and wherein at least about 7 heaters are disposed in the formation for each production well.

1095. (previously presented): The method of claim 1058, further comprising providing heat from three or more heaters to at least a portion of the formation, wherein three or more of the heaters are located in the formation in a unit of heaters, and wherein the unit of heaters comprises a triangular pattern.

1096. (previously presented): The method of claim 1058, further comprising providing heat from three or more heaters to at least a portion of the formation, wherein three or more of the heaters are located in the formation in a unit of heaters, wherein the unit of heaters comprises a triangular pattern, and wherein a plurality of the units are repeated over an area of the formation to form a repetitive pattern of units.

1097-5396. (canceled)

5397. (previously presented): The method of claim 1094, wherein at least about 20 heaters are disposed in the formation for each production well.

5398-5439. (canceled)

5440. (previously presented): The method of claim 1058, wherein the pyrolysis zone comprises a selected section.

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5441. (previously presented): The method of claim 1058, wherein at least one of the heaters is disposed in an open wellbore.

5442. (previously presented): A method of treating a hydrocarbon containing formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation, wherein one or more heaters provides a heat output of less than about 1650 watts per meter;

establishing a pyrolysis zone in at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to the pyrolysis zone of the formation;

controlling a pressure and a temperature in at least a majority of the pyrolysis zone, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure;

controlling a pressure in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than 25; and

producing a mixture from the formation.

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5443. (previously presented): The method of claim 5442, wherein the pyrolysis zone comprises a selected section.

5444. (previously presented): The method of claim 5442, wherein at least one of the heaters comprises a natural distributed combustor.

5445. (previously presented): The method of claim 5442, wherein at least one of the heaters is disposed in an open wellbore.

5446. (previously presented): The method of claim 5442, further comprising producing a mixture from the pyrolysis zone, wherein the mixture comprises condensable hydrocarbons having an API gravity of at least about 25°.

5447. (canceled)

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5448. (previously presented): The method of claim 5442, wherein providing heat from the one or more heaters to the portion of the formation comprises:

heating a selected volume (V) of the formation from one or more of the heaters, wherein the formation has an average heat capacity (C_v), and wherein the heating pyrolyzes at least some hydrocarbons in the selected volume of the formation; and

wherein heating energy/day (P_{wr}) provided to the selected volume is equal to or less than $\eta * V * C_v * \rho_B$, wherein ρ_B is formation bulk density, and wherein an average heating rate (η) of the selected volume is about 10 °C/day.

5449. (previously presented): A method of treating a hydrocarbon containing formation in situ, comprising:

providing heat from one or more heaters to at least a portion of the formation;

allowing the heat to transfer from the one or more heaters to a part of the formation;

controlling a pressure and a temperature in at least a majority of the part of the formation, wherein the pressure is controlled as a function of temperature, or the temperature is controlled as a function of pressure;

controlling a pressure in the formation to inhibit production of hydrocarbons from the formation having carbon numbers greater than 25; and

producing a mixture from the formation, wherein the mixture comprises condensable hydrocarbons.

5450. (previously presented): The method of claim 5449, wherein the part of the formation comprises a selected section.

5451. (previously presented): The method of claim 5449, further comprising establishing a pyrolysis zone in the part of the formation.

5452. (previously presented): The method of claim 5449, wherein at least one of the heaters comprises a natural distributed combustor.

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5453. (previously presented): The method of claim 5449, wherin at least one of the heaters is disposed in an open wellbore.

5454. (previously presented): The method of claim 5449, wherin the condensable hydrocarbons have an API gravity of at least about 25°.

5455. (canceled)

5456. (previously presented): The method of claim 5449, wherin providing heat from the one or more heaters to the portion of the formation comprises:

heating a selected volume (V) of the formation from one or more of the heaters, wherin the formation has an average heat capacity (C_v), and wherin the heating pyrolyzes at least some hydrocarbons in the selected volume of the formation; and

wherin heating energy/day (P_{wr}) provided to the selected volume is equal to or less than $h \cdot V \cdot C_v \cdot \rho_B$, wherin ρ_B is formation bulk density, and wherin an average heating rate (h) of the selected volume is about 10 °C/day.

5457. (new): The method of claim 5449, wherin controlling the temperature comprises maintaining a temperature in the pyrolysis zone in a pyrolysis temperature range.

5458. (new): The method of claim 5449, further comprising controlling a heating rate such that an average heating rate of the pyrolysis zone is less than about 1 °C per day during pyrolysis.

5459. (new): The method of claim 5449, wherin providing heat from the one or more heaters comprises heating the pyrolysis zone such that a thermal conductivity of at least a portion of the pyrolysis zone is greater than about 0.5 W/(m °C).

5460. (new): The method of claim 5449, wherin the produced mixture comprises condensable hydrocarbons, and wherin about 0.1 % by weight to about 15 % by weight of the condensable hydrocarbons are olefins.

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5461. (new): The method of claim 5449, wherein the produced mixture comprises non-condensable hydrocarbons, and wherein about 0.1 % by weight to about 15 % by weight of the non-condensable hydrocarbons are olefins.

5462. (new): The method of claim 5449, wherein the produced mixture comprises non-condensable hydrocarbons, wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons is less than about 0.15, and wherein the ratio of ethene to ethane is greater than about 0.001.

5463. (new): The method of claim 5449, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is nitrogen.

5464. (new): The method of claim 5449, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is oxygen.

G2
5465. (new): The method of claim 5449, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is sulfur.

5466. (new): The method of claim 5449, wherein the produced mixture comprises condensable hydrocarbons, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

5467. (new): The method of claim 5449, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmospheric absolute pressure, and wherein the

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molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmospheric absolute pressure.

5468. (new): The method of claim 5449, further comprising controlling the pressure in at least a majority of the pyrolysis zone of the formation, wherein the controlled pressure is at least about 2.0 bars absolute.

5469. (new): The method of claim 5449, wherein the produced mixture comprises hydrogen and condensable hydrocarbons, and hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

5470. (new): The method of claim 5449, wherein allowing the heat to transfer increases a permeability of a majority of the pyrolysis zone such that the permeability of the majority of the pyrolysis zone is substantially uniform.

G2
5471. (new): The method of claim 5449, wherein producing the mixture comprises producing the mixture in a production well, and wherein at least about 7 heaters are disposed in the formation for each production well.

5472. (new): The method of claim 5442, wherein controlling the temperature comprises maintaining a temperature in the pyrolysis zone in a pyrolysis temperature range.

5473. (new): The method of claim 5442, further comprising controlling a heating rate such that an average heating rate of the pyrolysis zone is less than about 1 °C per day during pyrolysis.

5474. (new): The method of claim 5442, wherein providing heat from the one or more heaters comprises heating the pyrolysis zone such that a thermal conductivity of at least a portion of the pyrolysis zone is greater than about 0.5 W/(m °C).

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5475. (new): The method of claim 5442, wherein the produced mixture comprises condensable hydrocarbons, and wherein about 0.1 % by weight to about 15 % by weight of the condensable hydrocarbons are olefins.

5476. (new): The method of claim 5442, wherein the produced mixture comprises non-condensable hydrocarbons, and wherein about 0.1 % by weight to about 15 % by weight of the non-condensable hydrocarbons are olefins.

5477. (new): The method of claim 5442, wherein the produced mixture comprises non-condensable hydrocarbons, wherein a molar ratio of ethene to ethane in the non-condensable hydrocarbons is less than about 0.15, and wherein the ratio of ethene to ethane is greater than about 0.001.

5478. (new): The method of claim 5442, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is nitrogen.

C2

5479. (new): The method of claim 5442, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is oxygen.

5480. (new): The method of claim 5442, wherein the produced mixture comprises a non-aqueous portion, and wherein less than about 1 % by weight, when calculated on an atomic basis, of the non-aqueous portion is sulfur.

5481. (new): The method of claim 5442, wherein the produced mixture comprises condensable hydrocarbons, wherein about 5 % by weight to about 30 % by weight of the condensable hydrocarbons comprise oxygen containing compounds, and wherein the oxygen containing compounds comprise phenols.

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5482. (new): The method of claim 5442, wherein the produced mixture comprises a non-condensable component, wherein the non-condensable component comprises molecular hydrogen, wherein the molecular hydrogen is greater than about 10 % by volume of the non-condensable component at 25 °C and one atmospheric absolute pressure, and wherein the molecular hydrogen is less than about 80 % by volume of the non-condensable component at 25 °C and one atmospheric absolute pressure.

5483. (new): The method of claim 5442, further comprising controlling the pressure in at least a majority of the pyrolysis zone of the formation, wherein the controlled pressure is at least about 2.0 bars absolute.

5484. (new): The method of claim 5442, wherein the produced mixture comprises hydrogen and condensable hydrocarbons, and hydrogenating a portion of the produced condensable hydrocarbons with at least a portion of the produced hydrogen.

G2
5485. (new): The method of claim 5442, wherein producing the mixture comprises producing the mixture in a production well, and wherein at least about 7 heaters are disposed in the formation for each production well.